

his death probably caused by flying timber. Here the path was about 200 feet wide.

The next damage was the destruction of a chair factory, housed in a large brick-veneered structure of three floors and basement. Although 114 men were at work when the building collapsed only 8 were killed; however, almost two score were injured. The factory was evidently directly in the path of the storm, for the roof lifted and the sides fell, some inward and some outward.

Sweeping toward the northeast the storm cut a swath about 300 feet wide through alternating factory and residence districts, missing a grade school by several hundred feet. At one point, about 500 feet north of the storm track, 4 boys, 14 to 17 years old, were hurrying home to escape the storm when a garage roof came hurtling through the air. Two of the boys were killed instantly and a third died later. The fourth was unhurt. Lifting the roofs from dwellings, breaking windows, tearing off porches, and uprooting trees as it proceeded the storm did further damage by removing the south wall of a factory, dropping the contents of the second and third floors, including a large water tank, to the basement. Two men were killed.

Moving on through an area of residence, narrowly missing two more schools it hit a factory section, blowing out the south wall of one building and the north wall of another across the street to the south. With a path 400 feet wide it crossed a railroad, and passed over a section of new homes, missing the fourth school by 1 block, moving 2 adjacent houses out in the street with not

a great deal of harm, damaging other residences with more or less severity. From this point the houses were scattered and open country was soon encountered. There was some skipping and scattered damage reported as far as Chemung. Several farm buildings were partially demolished and shade trees were broken down.

The visibility was good during the passage of the storm cloud, as workmen on a new building 3 miles away reported they saw the funnel-shaped cloud. There was much evidence of counter-clockwise motion and several walls were blown out. Débris was tossed out of the path toward the north. Porch roofs and eaves troughs were lifted and deposited on the main roofs, evidence of ascending air currents. The better class of structure withstood the storm's fury. A large reinforced concrete stack in the path was unharmed. There were some reports of hail, a very small amount. There was a moderate rain and some lightning. No fires were started.

The tornado struck the chair factory at 3:22 p. m. The exact time of other damage could not be determined with certainty, but the storm passed 2 miles south of Argyle and 1 mile north of Poplar Grove at 3:40 p. m., and the damage near Capron occurred near 4 o'clock. These facts indicate a velocity of forward movement of about 40 miles per hour. The length of the path was about 25 miles, the width varying from 200 to 500 feet. Fourteen deaths occurred and about 100 persons were injured in Rockford alone. Two hundred buildings were damaged or destroyed and the total property loss will amount to approximately \$1,200,000.

THE DISTRIBUTION OF EXCESSIVE PRECIPITATION IN THE UNITED STATES

By ALFRED J. HENRY

Excessive rains as defined by the United States Weather Bureau may be conveniently grouped as follows:

Class A. Twenty-four-hour rains equalling or exceeding 2.50 inches.

Class B. Five-minute rains equalling or exceeding 0.25 inch.

Class C. One-hour rains equalling or exceeding 1 inch; in the later records as much as 0.80 inch in an hour is considered as excessive.

This classification is based essentially upon a time scale of heavy rains. For the full 24 hours any rain of 2.50 inches or more, regardless of the fact that it may have fallen in but 1 or 2 hours, is put into the same class as those which may have fallen at a uniform rate of but 0.104 inch per hour. It is possible, therefore, that a particular rain may be classed in two groups. A still further classification based on the month as a time unit was in use for a time in the early years of the Federal Weather Service. Ten inches per month was considered as excessive.

A rainfall of 0.25 inch in 5 minutes (class B) is, of course, equivalent to the rate of 6 inches per hour. The amount of rain that falls in any 5-minute period rarely exceeds 0.50 inch as a maximum.

In assembling the statistics for the above-named groups the 24-hour rains form a class by themselves, since they are drawn almost exclusively from stick measurements of the ordinary rain gage and eye observations of the times of beginning and ending of the rain.

Classes B and C on the other hand are drawn mainly from automatic records of rainfall that give both intensity and duration of the fall. In a small number of cases stick measurements of very intense rains whose time of beginning and ending is accurately known have been used.

TWENTY-FOUR-HOUR RAINS

The 24-hour rains equalling or exceeding 2.50 inches have been tabulated by States and for the year and also for the 3 summer months separately. The period covered by the tabulations is the same, viz, 1871-1894. A total of 3,886 records of which 357 were for summer months was used. The ratio of summer to annual frequency is, therefore, about as 1:10. West of the Rocky Mountains there is almost an entire absence of heavy rains in summer due to lack of moisture in the atmosphere and the prevailing high temperature.

The winter rainy season on the Pacific coast yields on the average about 40 heavy daily rains per season, practically all of them being associated with traveling cyclonic storms. East of the Rocky Mountains the convective rains of summer added to those associated with cyclonic storms, cold fronts, etc., increases the total number of these rains to more than double the number experienced on the Pacific coast.

It is commonly held and apparently with justification that the total precipitation decreases with distance from the chief storehouse of water vapor—the oceans. Whatever the precise relation may be it is modified by the topography of the lands bordering the oceans and the direction of the prevailing winds and even more profoundly by the temperature-altitude relations, a subject that will be more fully touched upon later.

Figure 1 shows the distribution of Class A rains for the year and Figure 2 that for the three summer months of June-August. The distribution shown in the annual chart resembles somewhat that of the annual depth of

precipitation in the United States, the number of occurrences of heavy 24-hour rains being nearly proportional to the depth of annual precipitation with the following exceptions:

(1) The large number of occurrences in the Gulf and Atlantic States may be attributed in part to the proximity of large water surfaces; some further influence, however, must be effective to explain the fact that in the middle Gulf region—the States of Alabama, Mississippi, and Louisiana—heavy 24-hour rains are only about 75 per cent as frequent as in Florida and Texas. The Florida Peninsula is almost surrounded by water, otherwise the relative position of land and water surfaces is about the same. Nearly all of the summer rainfall in the Gulf of Mexico region is of convective origin, and it may well be that local influences should be more favorable in Florida and Texas than in the other States.

(2) There is also a secondary maximum of heavy 24-hour rains in the interior of the continent—see the record for the States of Iowa, Kansas, Nebraska, Missouri, and Illinois—and this maximum can not be explained on the ground of proximity to large bodies of water or intense local evaporation. I am of opinion that

and Virginia. Whether this decrease is real or due to a smaller number of rainfall records for these States I am not able to say. The distribution of rainfall stations is not uniform throughout the country, there being more stations along the eastern seaboard than in the interior or far Western States. It may be that if all States had as many and as long records of rainfall as are available for New England the frequency of heavy 24-hour rains would be greater than is here shown. The matter invites further study.

INTENSE RAINS OF SHORT TIME INTERVALS

I have used the records of 31 self-registering gages as summarized in Annual Report, Chief of Weather Bureau, 1895-96, pp. 247-64, for intervals of 5, 10, and 60 minutes. The summaries there published contain the records of 905 heavy downpours in 5 and 10 minutes. There is included in these summaries, however, the records of 53 rains of less intensity than was reached in the remainder of the rains. The explanation of this fact is, I take it, that it was thought necessary to give in each case of excessive rain for a 24-hour period the amount of rain for both the 5 and 10 minute and 1-hour periods regard-

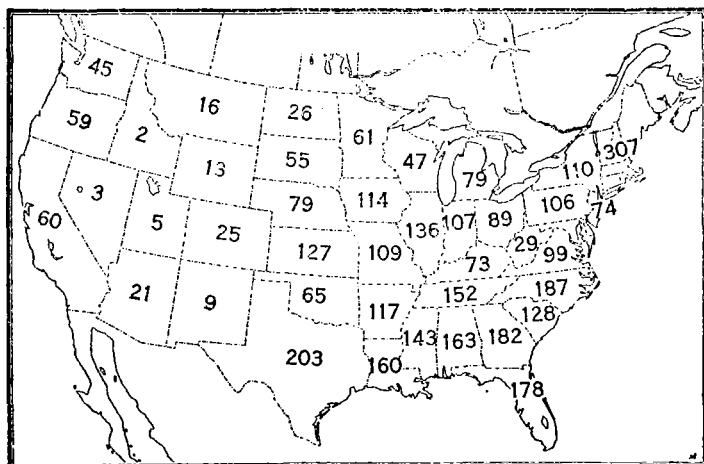


FIG. 1.—Distribution of 24-hour rains of 2.50 inches or more, total in 24 years, 1871-1894

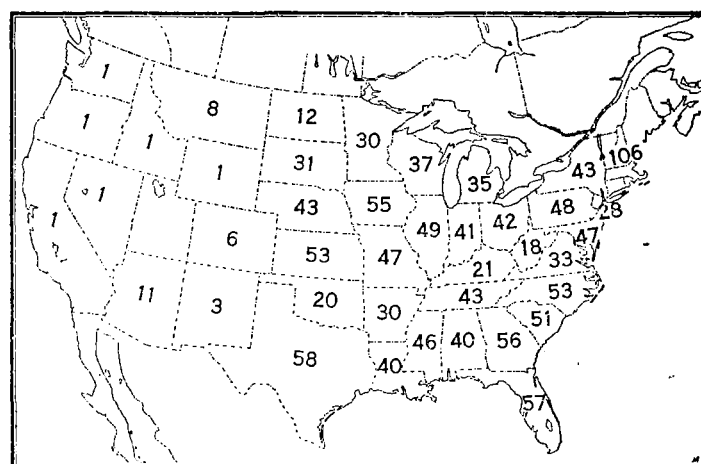


FIG. 2.—Distribution of excessive rains during summer for the five years, 1891-1895

the explanation will be found in the dynamic processes whereby warm moist air is permitted to ascend to elevations great enough to lower the temperature of the ascending moist air to its dewpoint, and thus to cause generous precipitation. This proposition assumes without proof, and there can be no direct proof, that in the warm seasons the atmosphere at the 3 to 4 kilometer level east of the Rocky Mountains is amply supplied at all times with sufficient water vapor to produce the observed rainfalls.

The old views on the causes of precipitation have given way to a certain extent to the modern conception of the atmosphere as being a series of concentric shells, each of which has the peculiar property that air which starts in any one shell can not be transferred to any other shell and remain there without the addition or subtraction of heat. The amount of water vapor in any shell, if large, greatly facilitates the air of that shell in rising to the level of condensation and thus causing generous precipitation.

A comparison of the data of Figures 1 and 2 shows that heavy 24-hour rains are frequent along the Gulf coast and in Florida, that the frequency diminishes with distance to the northward and then increases again in the lower Missouri Valley. It also shows a middle zone of lower frequency in Arkansas, Kentucky, West Virginia,

less of whether those amounts were great enough to come within the classification adopted for the 5 and 10 minute rains. I have, therefore, eliminated 53 of the records printed in the summary above-mentioned, leaving a total of 853 records for analysis.

In reading off the numerical values from the original instrumental trace sheets there seems to have been a tendency on the part of the observers who made the original computations to allocate the amounts of rain for the individual storms around certain prominent figures, such as 0.20, 0.25, 0.30, 0.35 inch, etc. The following example will clarify my meaning.

Number of cases of 0.20 inch.....	201
Number of cases of 0.21 inch.....	30
Number of cases of 0.22 inch.....	55
Number of cases of 0.23 inch.....	36
Number of cases of 0.24 inch.....	31
Number of cases of 0.25 inch.....	130
Number of cases of 0.30 inch.....	94
Number of cases of 0.35 inch.....	55

It is evident that a frequency tabulation would have little meaning. I have, therefore, classed the 5 and 10 minute rains in an ascending series and present the results in Table No. 1.

TABLE 1.—Rainfall intensities in 5 and 10 minutes classed as below, 1890-1895¹

Classes	Number in—		Classes	Number in—	
	5 min-utes	10 min-utes		5 min-utes	10 min-utes
0.20- inch	201		0.71-0.80 inch	2	24
0.21-0.30 inch	451	192	0.81-0.90 inch		7
0.31-0.40 inch	140	316	0.91-1.00 inch		6
0.41-0.50 inch	35	173	1.01-1.10 inches		2
0.51-0.60 inch	14	89	1.11-1.20 inches		1
0.61-0.70 inch	7	41			

¹ 1 inch in 1 hour or less, 265.

The above tabulation shows that the most frequent 5-minute rains are found in the class 0.21 to 0.30 inch, both inclusive.

Similarly the most frequent 10-minute intense rains are found in the class 0.31 to 0.40 inch, inclusive. The upper limit of the most intense 5-minute rains is in the group 0.71 to 0.80 inch, in which group but two cases are found in the five years of record. In the 10-minute group the upper limit is in the class 1.10 to 1.20 inch and only a single case was found in the records.

The average rate per hour of the 5-minute group is 3.30 inches, that of the 10-minute group drops to 2.40 inches; hence it may be inferred that on the whole the maximum intensity of short-period rains is reached within 5 minutes, and that increasing the duration of the rain lowers the intensity.

TABLE 2.—Rains equaling or exceeding a rate of 4.80 inches per hour, 1891-1895 (in 5 minutes)

Stations	5 min-utes	10 min-utes	60 min-utes or less	Duration in min-utes	Stations	5 min-utes	10 min-utes	60 min-utes or less	Duration in min-utes
	Inches	Inches	Inches	Inches		Inches	Inches	Inches	Inches
Atlanta, Ga.	0.45	0.65	0.76	60	Memphis, Tenn.	0.40	0.70	0.95	56
Bismarck, N. Dak.	.45	.67	1.05	60	Milwaukee, Wis.	.55	.80	1.26	60
Boston, Mass.	.40	.61	.90	60	New Orleans, La.	.42	.55	.68	53
Buffalo, N. Y.	.75	1.00	2.00	60		.68	.81	.82	45
Chicago, Ill.	.50	.80	1.50	60		.40	.75	1.76	60
Cleveland, Ohio.	.56	.83	1.68	60		.40	.67	1.12	60
Detroit, Mich.	.45	.75	1.70	60		.40	.55	1.23	60
Dodge, Kans.	.45	.80	1.60	60		.40	.55	1.44	50
Galveston, Tex.	.40	.65	1.60	60	New York, N.Y.	.60	.82	.90	60
Indianapolis, Ind.	.47	.61	.61	10		.40	.40	.41	25
Jacksonville, Fla.	.48	.50	.60	28	Norfolk, Va.	.42	.68	.91	45
Key West, Fla.	.60	1.00	2.15	60		.48	.91	1.00	60
Kansas City, Mo.	.40	.60	1.00	46		.45	.30	1.50	60
Los Angeles, Cal.	.47	.52	.63	60		.40	.66	2.20	60
London, Eng.	.50	.70	.95	60		.43	.63	1.71	60
Madison, Wis.	.43	.83	1.46	60	Omaha, Nebr.	.47	.75	1.45	60
Manila, P. I.	.40	.75	1.75	60		.50	.80	1.00	35
Memphis, Tenn.	.45	.75	.85	30	Philadelphia, Pa.	.50	.75	1.32	60
Minneapolis, Minn.	.54	.93	2.32	60		.45	.67	.85	28
Mobile, Ala.	.45	.65	1.60	60	St. Louis, Mo.	.40	.51	.86	60
Monterey, Cal.	.55	.65	.92	60		.40	.64	.97	60
Montreal, Can.	.42	.56	.57	60	St. Paul, Minn.	.70	1.00	1.30	60
Mountain View, Cal.	.49	.64	.71	60		.40	.70	1.35	25
Newark, N. J.	.62	1.18	2.20	60		.50	.70	1.10	51
New York, N. Y.	.60	.90	1.08	60		.40	.65	1.13	60
Omaha, Nebr.	.45	.80	1.30	23	Savannah, Ga.	.40	.50	.71	24
Philadelphia, Pa.	.54	.59	.66	60		.40	.65	1.35	60
Pittsburgh, Pa.	.40	.46	.87	60		.45	.80	2.20	60
Portland, Me.	.60	.77	1.73	60		.40	.80	1.10	60
Portland, Ore.	.55	.85	1.02	60		.40	.75	1.10	42
Portland, Vt.	.45	.75	1.75	60		.40	.70	1.05	60
Portland, Wis.	.45	.70	1.48	60		.47	.92	1.90	40
Portland, Wis.	.45	.63	.72	60		.50	.75	1.70	60
Portland, Wis.	.40	.80	1.55	60		.60	.90	1.98	60
Portland, Wis.	.45	.56	.95	60		.42	.70	.96	60
Portland, Wis.	.65	1.10	2.40	60		.68	1.05	2.28	60
Portland, Wis.	.47	.73	2.20	60		.43	.65	1.89	60
Portland, Wis.	.45	.65	1.56	60	Washington, D. C.	.40	.50	.65	58
Portland, Wis.	.41	.65	.90	33		.42	.68	.89	60
Portland, Wis.	.45	.80	1.13	60					
Portland, Wis.	.44	.72	1.85	33					
Portland, Wis.	.42	.65	1.13	50					

Another form of comparison leads to the result that the rate per hour during the 5-minute interval increased after passing to the 10-minute interval in but a fraction of 1 per cent of the total number of cases; the rate per hour held the same in 3 per cent and decreased in the remaining 97 per cent. As further illustrating variations in the intensity of the short-period rains, I have selected from both groups those rains having an hourly rate of not less than 4.80 inches for a 5-minute interval and have given the amount of rain that fell in each of these heavy downpours for intervals of 5, 10, and 60 minutes, respectively, in Table 2.

In this table there are 24 cases having the minimum rate of 4.80 inches per hour. The same 24 rains carried through a 10-minute period yield a rate of but 3.60 inches per hour and when carried through a period of 1 hour the rate sinks to 1.13 inches.

The geographic distribution of these rains is much the same as shown in Figure 2, except for the much greater frequency along the coast of the Gulf of Mexico and the coasts of Georgia and Florida. The intensity of the rains, however, is not greatly different as between coastal areas and the interior. In fact the greatest 5-minute intensity for the 5-year period occurred at Bismarck, N. Dak., far in the interior of the Continent. In the 10-minute period rains of great intensity have occurred at both Kansas City, Mo., and St. Paul, Minn. In the 1-hour class the greatest fall occurred at Kansas City, Mo., with Galveston, Tex., a close second.

The greater frequency of intense short period rains along the Gulf coast is doubtless due to the fact that the temperature of the dew point on the average, is much higher in winter and spring than it is in the northern frontier States.

It, therefore, follows that heavy rains occur along the Gulf coast throughout the year, whereas the average temperature of the dew point at Bismarck, N. Dak., for example is so low in winter that precipitation as rain is quite out of the question.

The average dew point at Galveston in winter is 40° to 45° higher than at Bismarck. In summer the difference is less—from 18° to 22° on the average.

The higher the temperature of the air, the greater its capacity for water vapor whence it follows that the precipitation must be more frequent and in larger amount in those regions having the higher dew point.

OCCURRENCE OF SHORT PERIOD EXCESSIVE RAINS AN ISOLATED PHENOMENON

On the whole the occurrence of excessive precipitation except in tropical cyclones, is more apt to be an isolated than a phenomenon of general distribution; occasionally, however, certain barometric depressions are exceptionally rich in excessive rainfall. On August 20-22, 1924, a rather weak depression of the trough type moving eastward north of the Dakotas gave excessive rain at Bismarck, N. Dak., and Moorehead, Minn., on the 20th and on the 21st at Minneapolis and St. Paul, Minn., Dubuque, Iowa, Wausau, Wis., Houghton, and Sault Ste. Marie, Mich. And on the 22d at Ludington and Grand Haven, Mich., Sandusky, Ohio, and Rochester, N. Y. The most remarkable feature, however, was two excessive rains on the 21st at both Minneapolis and St. Paul, Minn.

A summary of these rains follows:

Station (Aug. 21)	Excessive rain—			
	Began	Ended	Amount	Duration
	<i>A. m.</i>	<i>A. m.</i>	<i>Inches</i>	<i>Minutes</i>
Minneapolis.....	2. 19	3. 12	1.54	60
Do.....	6. 58	8. 02	1.57	80
St. Paul.....	2. 37	3. 25	1.08	50
Do.....	7. 18	7. 59	.90	45

The two gages in which the above amounts were recorded are about 10 miles apart, Minneapolis being to the northwest of St. Paul, and it will be noticed that there is a short time lag in the beginnings and endings at St. Paul as compared with Minneapolis, thus indicating a progressive movement of the rain at the rate of about 10 miles per hour. The total amounts at Minneapolis—the northwestern station—are greatest, thus perhaps indicating that the intensity of the rains was diminishing.

The source of the water vapor that produced at Minneapolis an inch and a half of rain in the early morning of the 21st and another like amount about 3 hours later, can not, of course, be definitely known. The surface winds before the rain began were from the southeast and the speed about 25 m. p. h. About 5 minutes before the excessive rain began the wind shifted to northwest and continued from that direction, although quite variable throughout the rain when it became northeast, and then east and southeast, continuing from those directions until the beginning of the second excessive rain. Then, as before, the wind suddenly shifted to the northwest soon becoming northeast and southeast after the rain had ended. It continued from those directions about 8 hours before finally backing to northwest through south and southeast.

The conclusion seems unavoidable that, not only was the vapor content of the air over the two stations much higher than the average, but also that the cooling which produced the condensation was in the nature of an intermittent advance of a cold front which, judging from the temperature did not extend to the surface as a solid current of cold air in either case.

The fact that both rains occurred during the hours when vertical convection must have been at a minimum lends support to the idea that the cooling at the level of condensation must have been due to the underrunning of colder air as the most probable cause of the excessive rains.

The cyclonic storm of July 7, 1915, with circular isobars and much stronger barometric gradients than are usually associated with a midsummer cyclone moved from eastern Nebraska on the morning of the 7th to Eastport, Me., by the morning of the 9th and central pressure fell to 29.16 inches by that time.

This storm was attended by numerous early morning thunderstorms in the middle Mississippi and lower Ohio Valleys and by heavy though not excessive rains in New England. The 24-hour rainfall was more than 3 inches at Binghamton, N. Y., Greenville and Portland, Me., and smaller amounts at other places. Excessive rains fell on the 7th at Davenport, Dubuque, and Keokuk, Iowa; Hannibal and St. Louis, Mo.; Chicago, Peoria, Springfield, and Cairo, Ill.; Terre Haute and Indianapolis, Ind.; Lexington, Ky., and Dayton and Cincinnati, Ohio.

Information as to the thermal stratification of the atmosphere in this cyclone is of course lacking.

THE AMOUNT OF AQUEOUS VAPOR IN THE ATMOSPHERE

The late Prof. C. Abbe, using Hann's law of the diminution of aqueous vapor with increasing altitude, computed the total amount of water vapor in the atmosphere up to 30,000 feet, (5.7 mile, 9.1 km.) in terms of depth of rain that it would produce if all were condensed. Abbe's results were based on the average surface dew point at the station; it rarely happens, however that rain falls when the dew point is at its average value, on the contrary rainfall generally occurs when the dew point is relatively high, hence the computed results are too low.

In 1915 the greatest excessive rain in any consecutive 24 hours was recorded at Iola, Kans., 4.90 inches in 1 hour and 25 minutes and the second greatest in the same year occurred at Corpus Christi, Tex., 4.70 inches in 1 hour and 20 minutes. At Iola the dew point just before the rain was 66° or 5° above the average for the month. The dew point at Corpus is not available. In both cases the excessive rains were associated with thunderstorms, except that at Corpus 2.09 inches of rain fell outside of the thunderstorm periods. For these 2 regions Abbe's computations based on the average dew point give 0.6 and 1.3 inches, respectively, the smaller amount being for Kansas and the larger for Texas. The actual rainfall was therefore six times as great as that computed at Iola and about four times as great at Corpus.

In the case of the last-named place the wind circulation may have brought fresh masses of saturated air over the station but at Iola the pressure gradient was not favorable to the indraught of air from outside regions; the gradients were weak and mostly for light south and southeast winds. In any event the fact remains and this is the point to be emphasized, that at this station, almost in the centre of the North American Continent the vapor content of the atmosphere as shown by the measured rainfall in less than 24 hours' duration was as great as at a point on the coast of the Gulf of Mexico, where all natural conditions were conducive to a high vapor content of the atmosphere.

The above is not an isolated case. At Topeka, Kans., in June of the same year 3 excessive rains were recorded as follows:

June 10, 4:19–4:35 a. 0.49 inch in 20 minutes.
June 10, 6:52–8:14 p. 2.02 inches in 100 minutes.
June 10, 9:24–9:39 p. 0.65 inch in 15 minutes.

At Minneapolis, Minn., 2.38 inches fell in 80 minutes, and this was followed later in the day by 0.47 inch in 15 minutes. While such cases can not be multiplied indefinitely, there are enough of them to cause us to believe that our knowledge both of the source and amount of aqueous vapor in the atmosphere is incomplete.

THE 3-DAY RAIN OF OCTOBER 4–6, 1910

This paper would be incomplete without reference to the continued rains of October 4–6, 1910. This was an extraordinary rainstorm coming as it did in one of the dry months of one of the driest years ever experienced in this country. It had one feature in particular that is seldom found outside of tropical cyclones, viz, a concentration of heavy rains in one or more separate areas. In this in-

stance there were at least 4 such areas, 2 in Arkansas, and 1 each in southeast Illinois and Missouri. The 3-day totals for each of these areas follow:

of large tornado frequency in the United States.¹ The area inclosed by the isohyet of 7 inches includes approximately 42,000 square miles. In and close to this area

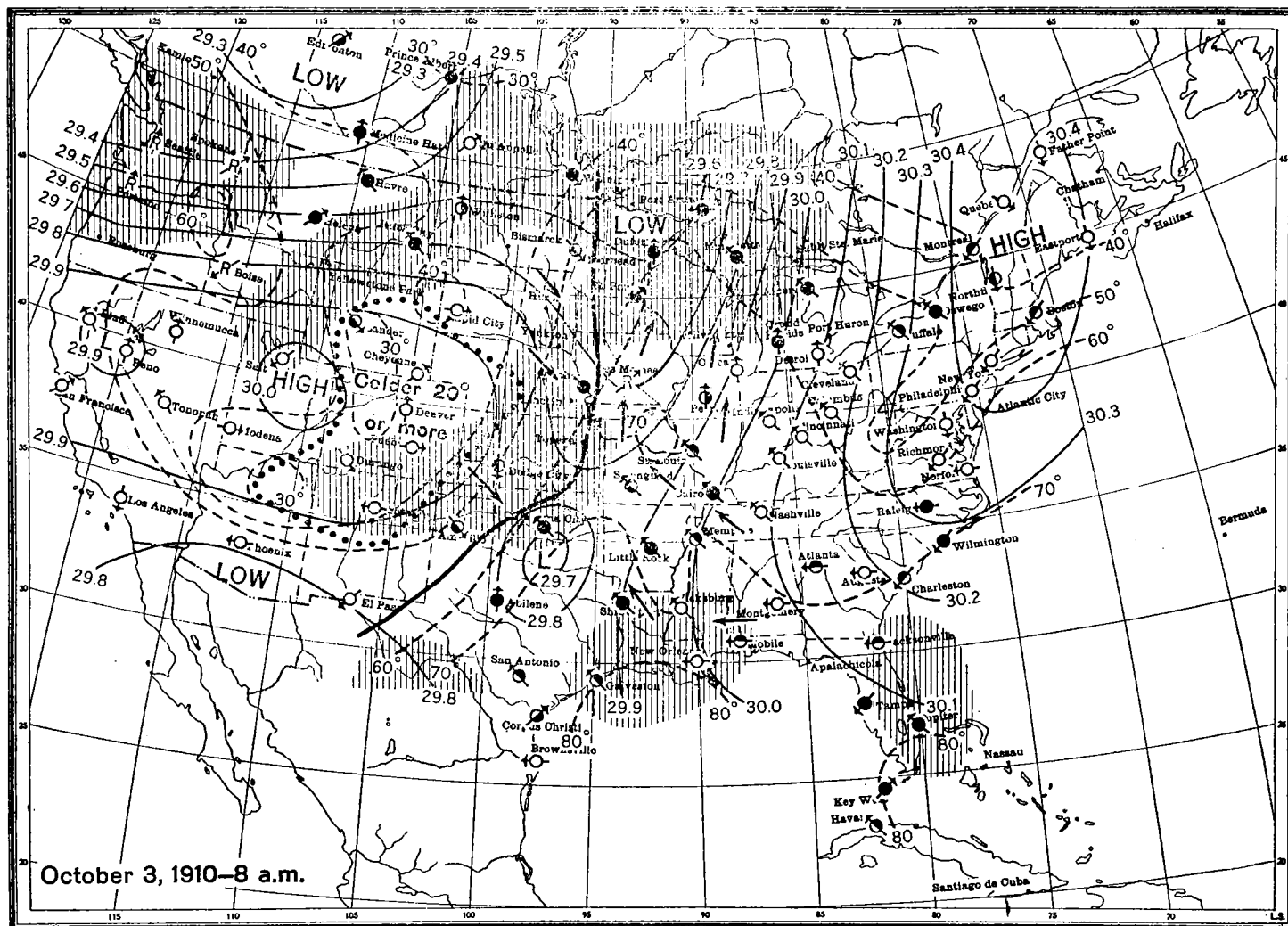


FIG. 3a.—Daily weather map

	Inches
Bee Branch, Ark.....	11.50
Marked Tree, Ark.....	13.99
New Madrid, Mo.....	13.30
Golconda, Ill.....	15.18

The longer axis of the storm, as may be seen from Figure 4 extends in a NE.-SW. direction, closely paralleling the Ohio River from Cincinnati to the mouth at Cairo. It may be only a coincidence but the area of heavy precipitation as here figured is very nearly coextensive with that

there were 16 self-recording rain gages 13 of which gave a record of excessive rains. Five other gages outside of this central region furnished records of the duration and intensity of the precipitation for other parts of the same storm. I have summarized these 21 records in Table 1 and present it as a record of perhaps the most widespread heavy rainstorm that has occurred in many years.

¹ There are reasons for believing that the atmospheric conditions which produce thunderstorms and tornadoes are closely related. These conditions are nowhere so fully developed as in the great interior valleys between the Rockies on the West and the Appalachians on the East.

TABLE 1.—Excessive rains October 3-8, 1910

Stations	October, 1910						Amount previous to beginning of excessive rate	Accumulated amount	Duration
	3	4	5	6	7	8			
Del Rio, Tex.	2:14 a. m.						Inches 0.06	Inches 0.51	Min. 20
Taylor, Tex.	7:53 a. m.						0	.39	10
Little Rock, Ark.		12:45 a. m.					.04	1.62	100
Cairo, Ill.		4:18 a. m.	12:47 a. m.				1.78	3.34	180
			8:51 a. m.				.08	.53	20
Evansville, Ind.		8:13 a. m.					.29	.77	50
		9:38 a. m.					1.38	.86	50
			3:47 a. m.				2.32	1.23	50
			6:08 a. m.				.53	.85	50
San Antonio, Tex.		9:47 a. m.					1.66	.97	45
Louisville, Ky.		2:22 p. m.					.29	.44	15
				1:34 a. m.			.01	.68	30
Fort Smith, Ark.			4:40 p. m.				3.37	.75	45
Cincinnati, Ohio.			4:41 p. m.				.03	.79	20
				3:09 a. m.			.32	.64	40
Memphis, Tenn.			6:11 p. m.				2.46	.86	40
			7:41 p. m.				.46	.61	30
			8:52 p. m.				1.32	.76	35
Galveston, Tex.				12:42 a. m.			2.12	.44	10
Mobile, Ala.	11:04						.07	6.28	120
				3:16 a. m.			.02	1.40	80
				8:36 a. m.			1.23	1.00	80
							.03	.98	45
Thomasville, Ga.		5:41 p. m.					.01	2.35	80
Nashville, Tenn.				3:54 a. m.			.25	.75	40
Vicksburg, Miss.				4:11 a. m.			.15	1.13	80
Anniston, Ala.				3:05 p. m.			.02	1.10	80
Asheville, N. C.					3:29 a. m.		.66	.51	30
Raleigh, N. C.					12:49 p. m.		.01	.70	35
Macon, Ga.					5:48 p. m.		.70	.80	35
Augusta, Ga.					10:09 p. m.		.56	.92	50
Charleston, S. C.						4:03 a. m.	1.14	.39	10

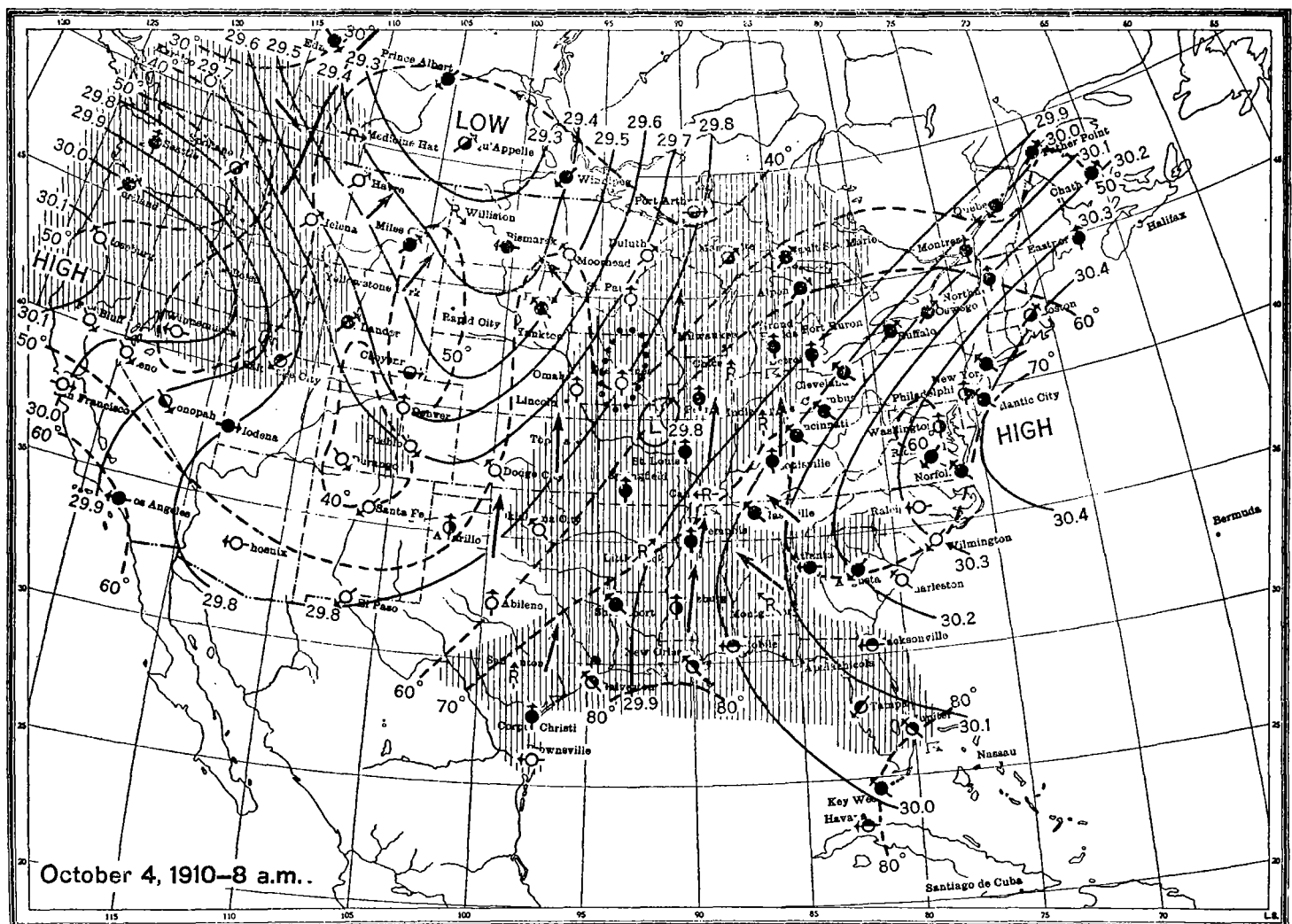


FIG. 3b.—Daily weather map

This table shows that the first excessive rain fell on October 3 in the Rio Grande Valley at Del Rio, Tex.; the second in point of time at Taylor, Tex., almost directly northeast and distant about 200 miles from Del Rio; the third occurred at Mobile, Ala., later in the day, and it may well be thought of as being independent of the conditions that caused the rain in Texas. There was then on the first day of the rains no concentration over any one district that was so noticeable on the 4th, 5th, and 6th of October. On October 4 excessive rains were confined to a rather narrow strip of territory that ex-

At Houston, Tex., about 50 miles inland from Galveston, the fall was but 0.43 inch, and at 16 other stations near the coast individual falls ranged from zero to 1.40 as the largest, the average being 0.50 inch.

Whatever the temperature-pressure-altitude relations in the free air over Galveston it must be inferred that they were local to that station. West of Galveston there was no rain of consequence on the 6th.

The data of the table show the beginning of excessive rains in southwestern Texas, a concentration in the lower Ohio and middle Mississippi Valleys, and finally a passage

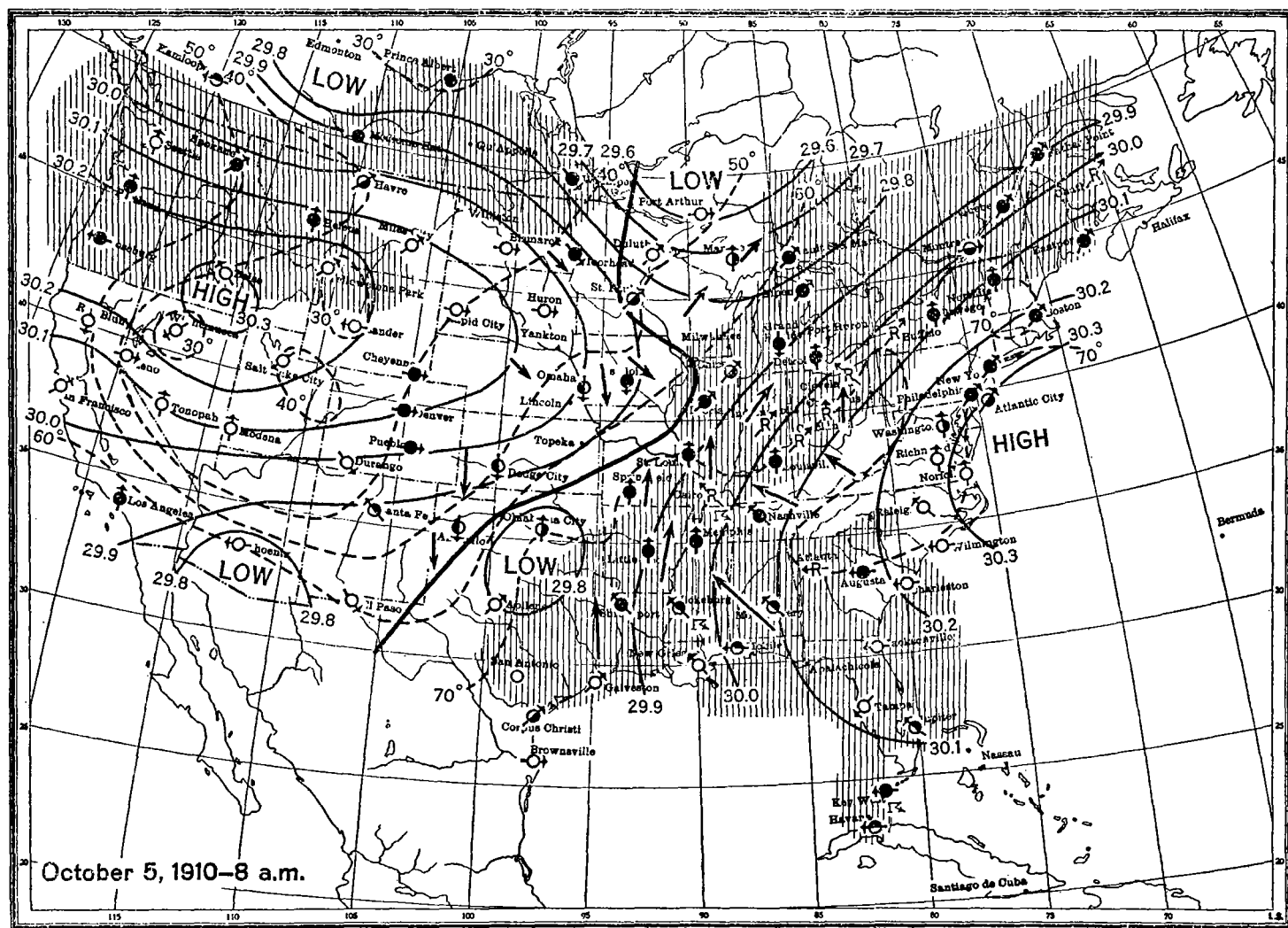


FIG. 3c.—Daily weather map

tended in a NE.-SW. direction from San Antonio, Tex., to Louisville, Ky., with great intermediate spaces where, perhaps from a lack of gauges, no records were obtained. In this strip several weather bureau stations are located, each having an automatic gauge in operation. It so happened that good records, both of duration and intensity, were obtained, particularly at Cairo, Ill., Evansville, Ind., and Memphis, Tenn.

The most striking fall was that recorded at Galveston, Tex., on the 5th, viz, 6.28 inches in 2 hours. The unusual feature being not so much the amount and intensity of the fall at Galveston as the relatively small rains inland a few miles.

off to sea over the coast of South Carolina on the early morning of the 8th.

I now pass to a consideration of the daily weather charts, October 3 to 6th, both inclusive.

The charts, Figure 3.—To those accustomed to read them the charts speak for themselves; to the lay reader they very likely mean but little. The essential features are as follows:

October 3, beginning of the rains.—A trough of low-pressure stretches from Texas to the Canadian border and is flanked on either side by high pressure, that over New England being much the higher of the two. The western area, however, is associated with a fall of about

20° in the surface temperature that had advanced into the western borders of the plains States of Nebraska, Kansas, and Oklahoma.

October 4, beginning of heavy rains in Missouri.—The outstanding feature of this chart is the advance of a fresh depression of the barometer from the Canadian Northwest. This depression was of the V type, its southern end, the apex of the V had extended well into the Plains States. The pressure trough of the 3d has remained in practically the same position it was in on that date, except that the northern end is a little farther to the east-

and from the north on the west or cool side. It is reasonable to assume that the thermal stratification of the atmosphere where the heavy rains fell was such as to warrant the fall of rain as recorded at the several rainfall stations. Unfortunately no data are available for the free air over the interior valleys on the dates in question, but enough is known from the pressure formations as indicated in the charts to infer that the surface wind directions also prevailed aloft and judging from the amount of precipitation that occurred there must have been enough speed to have brought in large masses of air from distant regions.

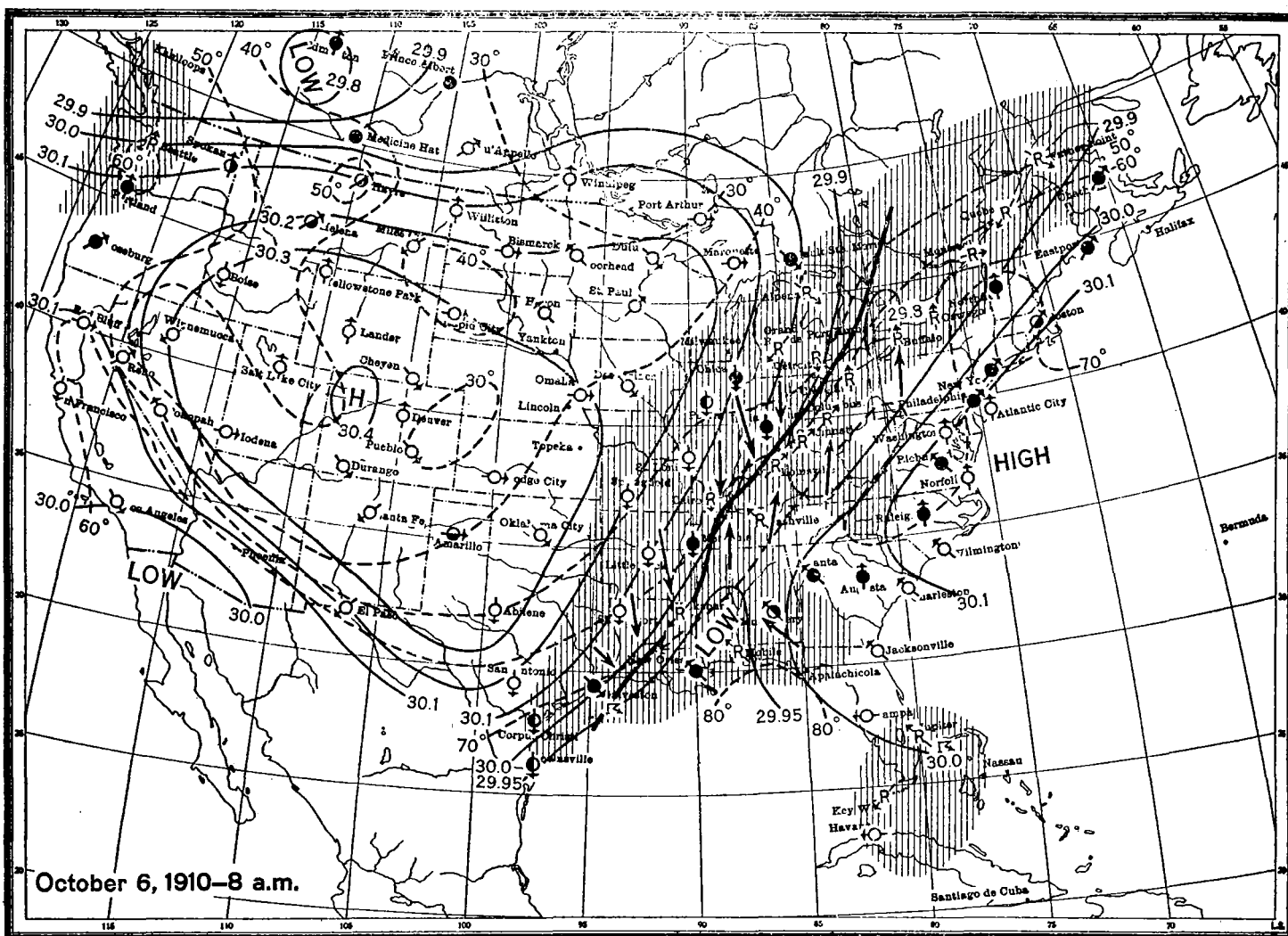


FIG. 3d.—Daily weather map

ward than the southern. The wind shift line of the 3d has now disappeared east of the Rocky Mountains and a fresh trough of low pressure has advanced over the region occupied by a similar one 24 hours earlier.

October 5, second day of heavy rains.—As just stated a second trough of low pressure now occupies almost the identical position of that which overlaid the same region on the 3d and 4th. This is the keynote of the situation and fully explains the continuance of heavy rains over the region in question. I have drawn the wind shift line for each of the dates and have indicated by the large arrows on either side of it the general drift of the surface layers of air—from the south on the east or warm side

October 6, conclusion of heavy rains.—On this date heavy rains fell only in western Kentucky and western Tennessee, also in the extreme southeastern tip of Missouri, thus showing that the overlapping of the two troughs of low pressure was not great. The width of the zone of greatest rainfall at its widest point was about 250 miles and its extreme length about 600 miles.

Finally, the outstanding result of this study is the fact that the atmosphere over the United States, say east of the one-hundredth meridian contains during the warm season a high water content which awaits only suitable temperature relations in order to produce excessive rains for a short period of time.

The longer excessive rains (24 hours) are due as a rule to any one of the following conditions: The advent of a tropical cyclone along the Gulf and the eastern seaboard. The seemingly fortuitous relative geographic position with reference to each other of a vigorous extratropical cyclone with a strong anticyclone immediately to the

northeast. The same condition, although in a slightly different form, viz, the intrusion of an anticyclone (cold front) into an extensive barometric trough wherein high temperature and vapor content in the atmosphere prevail, also causes excessive rains for 24 hours and sometimes longer.

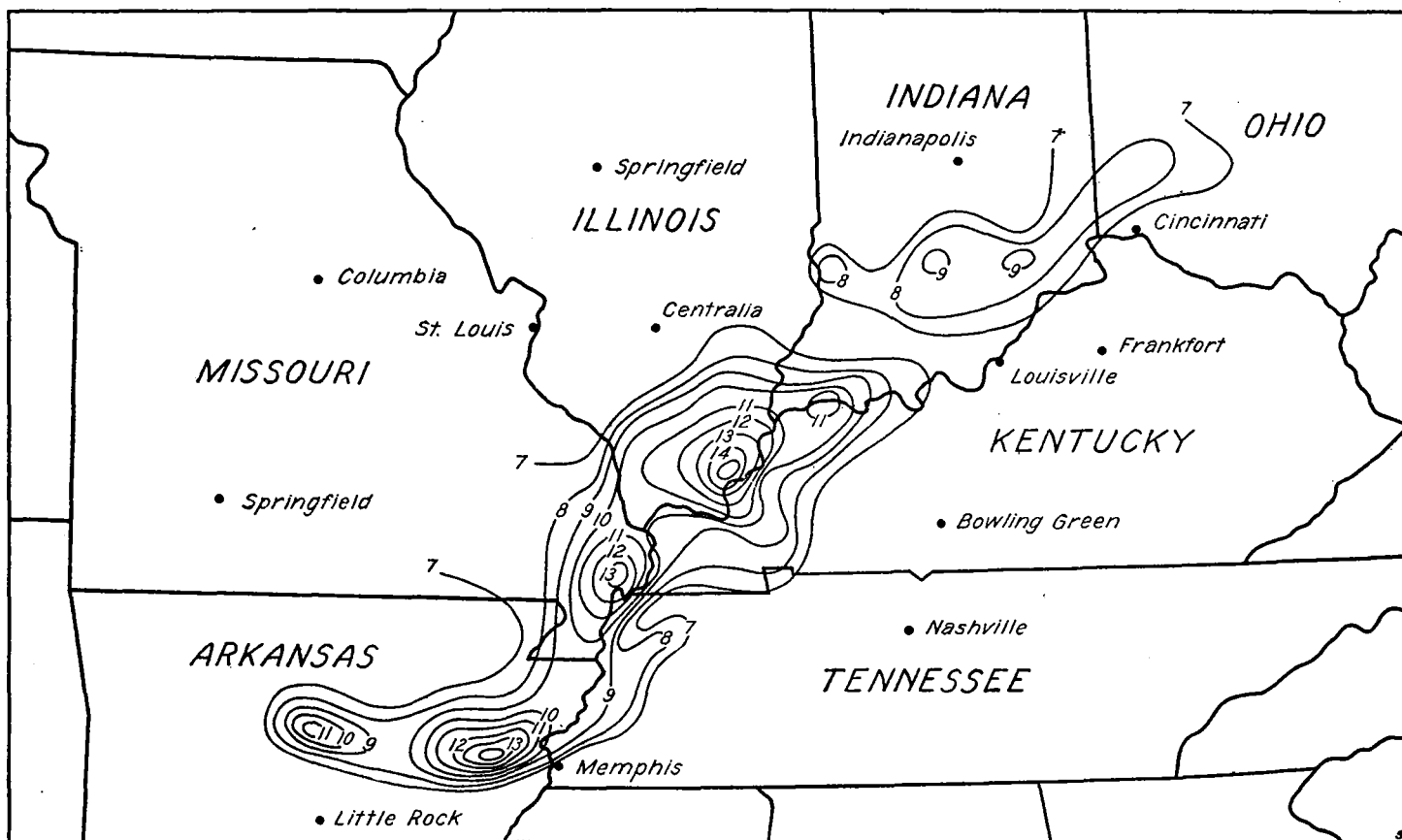


FIG. 4.—Heavy rains in Ohio Valley, October 4-6, 1910

RECOVERY FROM SUBNORMAL TEMPERATURES

By I. R. TANNEHILL

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The cold wave having arrived, interest is directly turned to the rate of recovery to temperatures approximately normal. In some instances the cold lingers for days and the recovery is gradual while in other cases an abrupt change to much higher temperatures quickly follows. Public interest in the return to seasonable conditions is aroused not alone by its effect upon human comfort but because the rate of recovery is one of the factors determining the extent of injury to vegetation.

In discussing injurious temperatures, Young (1) says:

So many factors must be taken into consideration in determining whether a given temperature will cause damage that the matter is one of great complexity. The length of time the low temperature persists, the vigor and stage of advancement of the plant, the kind of weather preceding the frost, and the rate of thawing all have considerable influence on the amount of damage that will be done.

The marked differences in rate of recovery from cold waves at Galveston is illustrated by the occurrence in January, 1887, of a temperature of 24° with only one day below freezing, while in January, 1886, the temperature

was below freezing for seven consecutive days, with a minimum of 11°. The lower temperature in the latter instance was only in part responsible for the duration of freezing temperatures, as in February, 1899, the temperature fell to 8° with only three days below freezing.

This study was undertaken to determine the relative frequencies of temperature rises of various magnitudes, the relation of current temperature to the probability of a rise, and the influence of pressure distribution upon the rate of recovery from low temperatures.

As a basis for the study, all 7 a. m. temperatures in the period 1901 to 1925, inclusive, were examined, numbering 9,131 in all. Files of weather maps covered the periods 1901 to 1905 and 1914 to 1925, though not complete for the latter period. Weather maps and temperature changes in the winter months were studied chiefly, because at that season the frequency and average magnitude of temperature rises are greatest.

For the purposes of this paper a temperature rise is considered only when exceeding the stationary limit, namely, 10° in December, January, February, and March,